WHOI-79-3 C.2

Woods Hole Oceanographic Institution

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ARCHIVED TIME-SERIES OF ATLANTIC OCEAN METEOROLOGICAL VARIABLES AND SURFACE FLUXES

by

Andrew F. Bunker
and
Roger A. Goldsmith

January 1979

TECHNICAL REPORT

Prepared for the Climate Dynamics Research Program, Division of Atmospheric Sciences, National Science Foundation under Grant ATM 77-01475 A01.

WOODS HOLE, MASSACHUSETTS 02543

Omissions and Errata for Technical Report WHOI-79-3

Archived time-series of Atlantic Ocean

Meteorological variables and surface fluxes

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Page 3. Substitute the enclosed figure for Figure 1.

Page 4. Insert τ on the left-hand side of equation (3).

Page 7. Change the sense of the sentence starting on line 8 by placing a period after ' in these cases' and starting a new sentence: A '+' was written on the tape to indicate observed ice averages.

Acknowledgment:

The authors wish to acknowledge the help of Dr. Woollcott K.Smith, Statistician associated with the Information Processing Center of the Oceanographic Institution. Dr. Smith helped us in the planning stage of the project by guiding us to the best mathematical techniques and programs for computing statistical parameters and their confidence limits.

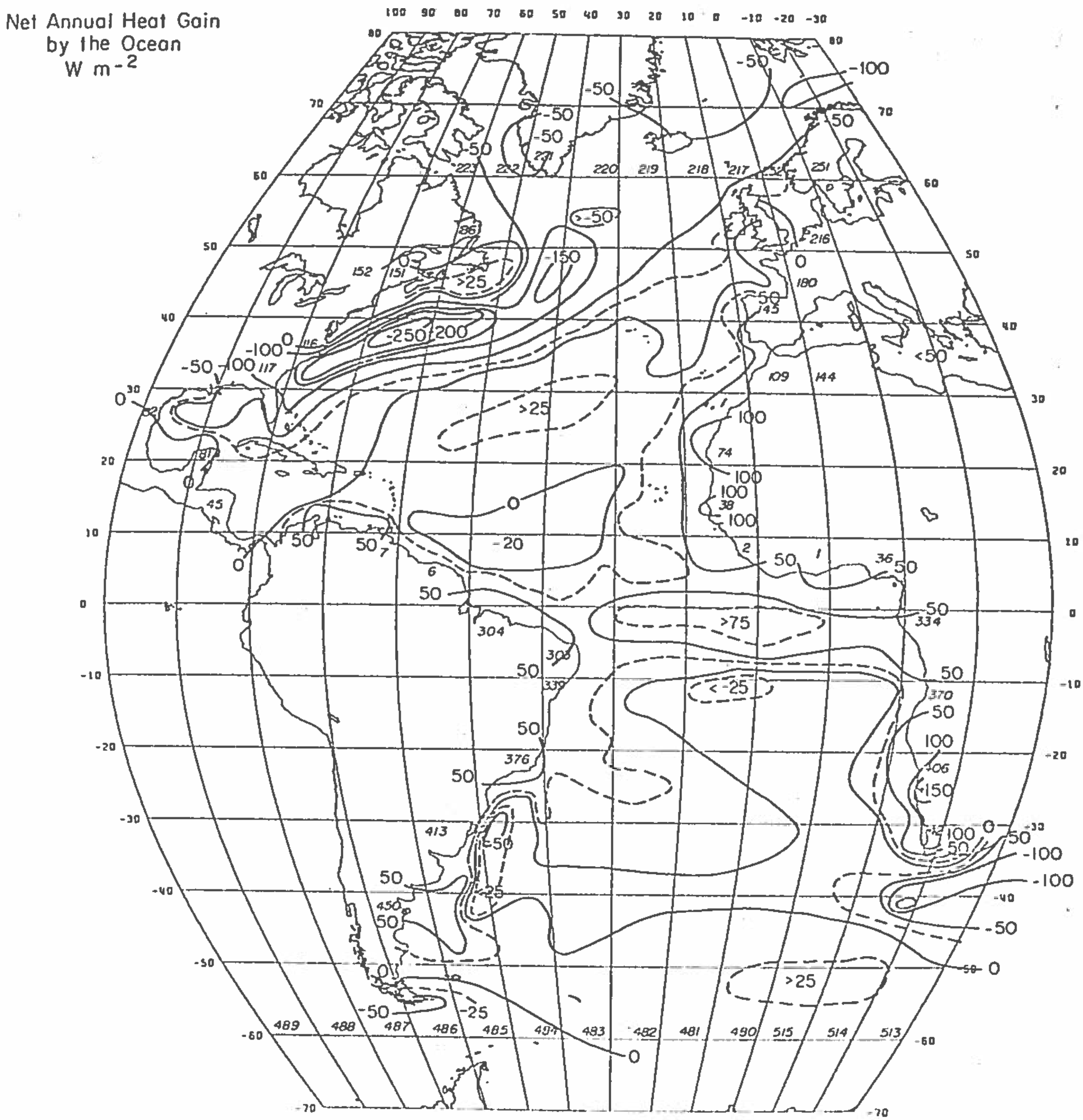

Figure 1. Chart of the net annual heat gain by the ocean. W m^{-2}.

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Approved for Distribution: ______________________
V. Worthington, Chairman
Department of Physical Oceanography

Abstract

Time-series of monthly averages of latent, sensible and radiational heat fluxes and momentum fluxes at the surfaces of the North and South Atlantic Oceans were calculated from ship weather observations. These fluxes, together with values of meteorological variables have been averaged over entire Marsden squares (10×10° squares) for all months from January 1948 through December 1972. The method of computing fluxes from ship weather observations, listing of variables averaged, addition of sea-ice coverage of sub-polar regions, correction of albedos for the presence of sea ice, correction of infrared radiational exchange for humidity conditions of the upper atmosphere, and format of the data on magnetic tapes are described. Statistics of the fluxes and variables have been computed. Standard data tapes containing these time series and statistics are available.

1. Introduction

The exchange of heat, water vapor, and momentum between the ocean and the atmosphere has many far-reaching effects, some very obvious and some very subtle, upon oceanic circulations and properties and upon atmospheric changes. To understand the physical processes operating in both media and to study climatic changes it is necessary to have a satisfactory knowledge of both the long-term averages of fluxes and variables and the short-term anomalies. Fluxes have been computed under another project[1] by substituting ship weather observations into empirical formulas as described by Bunker (1976). Figure 1, the net annual heat gain by the ocean, is presented here as an example of long-term averages computed by the project.[2] During the computational process averages of meteorological variables and fluxes were punched out on cards for each month during the 1948 to 1972 period. Under the present project these cards have been checked, added to, and corrected as will be described later. The final time sequence of monthly averages has been transcribed onto magnetic tapes which are available to all marine and atmospheric scientists at cost of reproduction. The authors are now engaged in analyzing the series to determine the relationships between the anomalies of selected variables.

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[1] Water Mass Formation supported by ONR Contract N00014-74-C-0262.

[2] It will be noted that averages differ somewhat from charts published by Bunker and Worthington (1976) and Bunker (1976). The change was produced by corrections to the infrared exchanges for regional upper air abnormalities of humidity. See Section 3c.

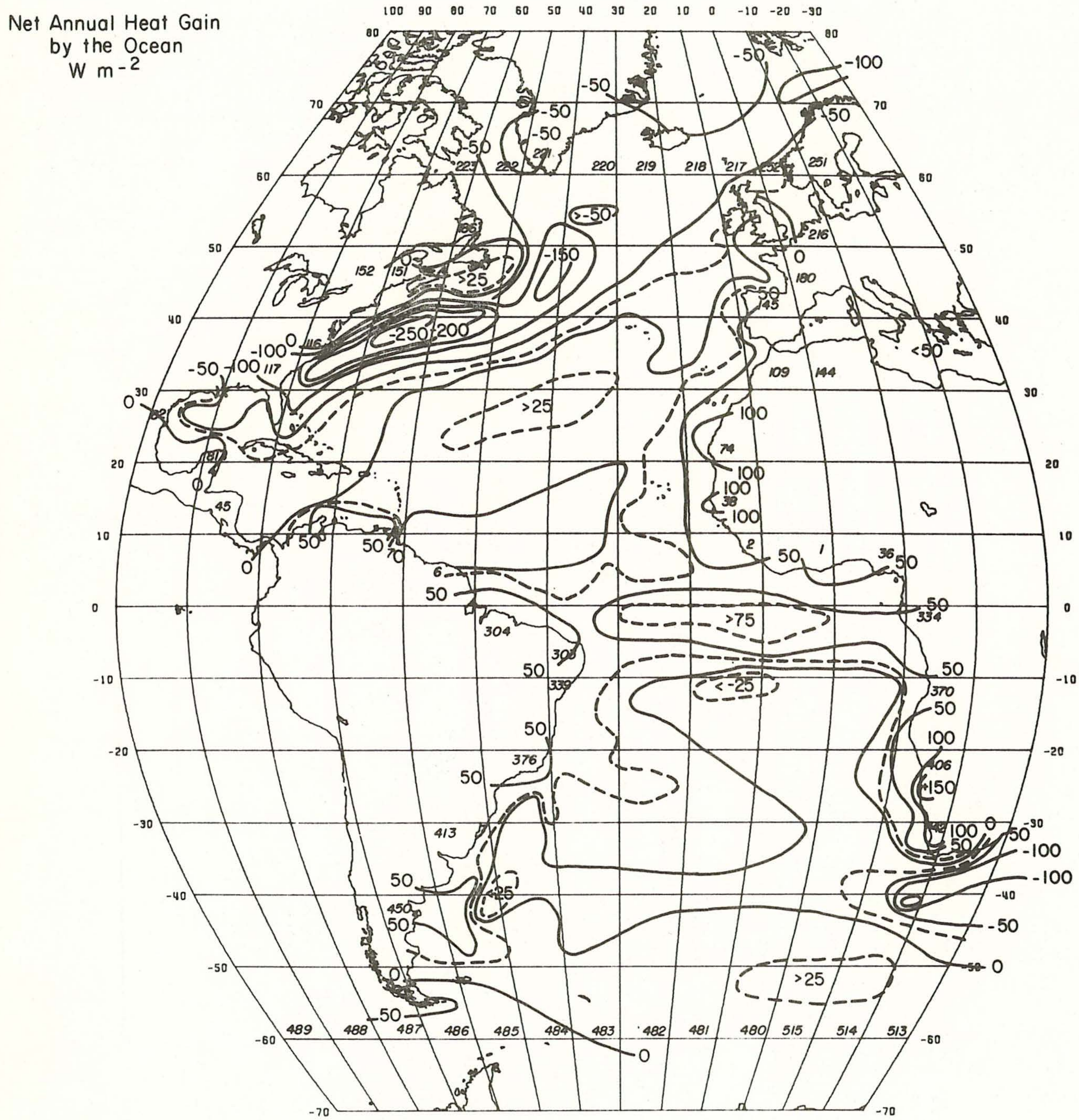

Figure 1. Chart of the net annual heat gain by the ocean. W m^{-2}.

2. Computation of fluxes and monthly averages of fluxes and variables

Ship observations used were supplied by the National Climatic Center. The Center has collected, checked for quality, and recorded on magnetic tape over 35 million observations from the world oceans.

The method of computing fluxes from weather observations taken aboard ships of opportunity is described in detail by Bunker (1976). The system will only be summarized here. Bulk aerodynamic equations with exchange coefficients which varied with wind speed and atmospheric stability were used to compute fluxes from observed gradients between the surface and deck level (10 m) and the wind speed as follows:

Latent heat flux: $$LE = \rho C_E L(q_s - q_{10})U_{10} \ . \tag{1}$$

Sensible heat flux: $$S = \rho C_H c_p (T_s - T_{10})U_{10} \ . \tag{2}$$

Wind stress: $$= \rho C_D U_{10}^2 \ . \tag{3}$$

Here the symbols have their usual meteorological meaning. The stress value computed from (3) was resolved into the x and y components before averaging. Tables in Bunker (1976) give the variation of the exchange coefficients with wind and stability. Fluxes were computed from each individual ship observation and later averaged with other fluxes determined in the same area and month. Only those sets of ship observations were used which furnished values for all of the variables indicated in (1), (2), and (3), and which were needed for radiation estimation. Long-term monthly flux averages were found by summing individual flux values for a given month and subdivision of a Marsden square over all years and dividing by the total number of observations.

Averages for individual months were found by summing all flux values computed for that particular month in an entire Marsden square and dividing by the number of observations.

Radiational heat exchange was found from monthly averages of cloud cover and tables following the method used by Budyko (1963). As will be discussed later, the infrared averages required corrections. Monthly averages of meteorological variables were formed from the individual ship observations which had all the required variables in the same manner as flux averages were formed. The list of meteorological variables and computed fluxes is given in Table 1.

3. Additions and corrections to the data set

a) Sea Ice Coverage

Significant changes in the albedo, latent heat flux and sensible heat flux occur when the sea is covered with ice and snow. The albedo increases greatly from values around 0.06 to values which can range from 0.1 up to 0.85 depending on the ice age, dirt content, snow cover, and melt water. This change makes corresponding changes in the solar radiation absorbed by the surface. Large changes in infrared exchange, sensible and latent heat flux occur because heat flow through the ice is slow and the ice surface becomes much colder than the water surface. Probably wind stresses also are modified by the ice cover, but no attempt to correct stress values over ice have been made.

The first step toward determining corrections to the fluxes due to ice was to establish a monthly series of ice coverage values for each Marsden square. A sea-ice ratio was defined as the product of the mean

TABLE I

Table of climatological parameters and corresponding access identifiers

Parameter	Units	Identifier	Data Element	Data Type
Marsden square		MSQU	1	1 - integer
year		YEAR	2	1 - integer
month		MON	3	1 - integer
number of observations		NOBS	4	2 - real
air temperature	°C	TAIR	5	2 - real
mixing ratio	G/KG	MIXR	6	2 - real
sea surface temperature	°C	TSEA	7	2 - real
air-sea temperature difference	°C	TASD	8	2 - real
cloud cover	OKTAS	CLOU	9	2 - real
wind speed	METERS/SEC	WIND	10	2 - real
east wind component	METERS/SEC	EAST	11	2 - real
north wind component	METERS/SEC	NORT	12	2 - real
direction of resultant wind	° FROM 0 NORTH	WDIR	13	2 - real
ratio of rain to total observation		RAIN	14	2 - real
sea level pressure	PASCALS/100	PRES	15	2 - real
ratio of sea ice		ICER	16	2 - real
effective radiation at surface	WATTS/METER**2	QSUR	17	2 - real
infrared radiation	WATTS/METER**2	IRED	18	2 - real
radiation exchange	WATTS/METER**2	REXB	19	2 - real
latent heat flux (Budyko)	WATTS/METER**2	LATB	20	2 - real
sensible heat flux (Budyko)	WATTS/METER**2	SENB	21	2 - real
heat gain of ocean (Budyko)	WATTS/METER**2	OHGB	22	2 - real
latent heat flux (by observation)	WATTS/METER**2	LATI	23	2 - real
sensible heat flux (by observation)	WATTS/METER**2	SENI	24	2 - real
heat gain by ocean (Budyko, observation)	WATTS/METER**2	HGBI	25	2 - real
wind stress, east component	PASCALS	TAUX	26	2 - real
wind stress, north component	PASCALS	TAUY	27	2 - real

fraction of the area of a Marsden square enclosed within a line separating fast ice or sea ice from open ocean times the mean concentration or fractional coverage of water area by ice within the ice boundary. Early in the work it was recognized that insufficient observations existed in the South Atlantic. Hence a climatological average has been used for each month and 10 degree square in that region. In arctic regions observations were more plentiful but still many months had no observations taken in some squares. Climatological means were inserted into the series in these cases and a '+' written on the tape to indicate this type of average. Climatological averages were used also for months when ice observations were sparse, uncertain, or contradictory. For months with no ship observations of weather, no ice ratios have been recorded on the tapes. A bibliography of sea ice observations will not be given here because it is so extensive. In spite of the large number of ice observations published, the final tabulations should be considered as very crude estimates of the ice coverage. This is so because of the vast areas involved and the rapidity with which ice fields can be consolidated or dissipated by the wind. Other sources of inaccuracy are different definitions of ice coverage which are accepted as delineating the edge of an ice pack. During the period studied the method of observation changed radically from a) occasional eyeball observations by men on hills, ships, or airplanes; to b) methods of a) plus reconnaisance flights by military aircraft equipped with radar and cameras; and finally to c) methods of a) and b) plus photographs taken from satellites. Hence the accuracy of the estimates increased during the period. However, even in the last few years of the period one cannot claim to have an accurate time-average of the percentage of area covered by ice because the pack shifts rapidly and the percentage coverage within packs is hard to estimate.

b) Flux corrections necessitated by the presence of ice

To correct estimates of solar radiation absorbed by the ocean, mean values of the albedo of the ice must be determined. After studying the work of Larsson and Orvig (1961)(1962) and many other workers in the field, it was decided to accept 0.8 as a reasonable approximation of the albedo for November through March and 0.5 for April through October in the Northern Hemisphere. In the Southern Hemisphere the months differ by 6 months. New values of the radiation absorbed by the ocean were computed from the formula:

$$Q_{c,a} = (1\text{-SIRAT})Q_c(1\text{-alb}_w) + (\text{SIRAT})Q_c(1\text{-alb}_{ice}) \qquad (4)$$

where $Q_{c,a}$ is the solar radiation absorbed by a partially ice-covered ocean surface during a given month with a given cloud cover; Q_c is the radiation arriving at the surface; SIRAT is the sea-ice ratio; and alb_w and alb_{ice} are the albedos of the water and the ice.

Vowinkel and Orvig (1973) present monthly fluxes of infrared radiational, latent, and sensible heat for ice with 1 and 4 m thickness. From their results a table was constructed giving the net infrared radiational exchange at the ice surface divided by the net infrared radiational exchange at the water surface. Since conditions vary widely in the region north of a line from Newfoundland to Svalbard, these ratios can be considered only as an approximation of conditions in the area.

TABLE II

Ratios of net infrared radiational exchanges at the surface of sea ice to exchanges at the ocean surface in the Northern Hemisphere
Lag 6 months for S.H.

Month	Ratio	Month	Ratio	Month	Ratio	Month	Ratio
January	0.16	April	0.24	July	0.81	October	0.22
February	0.15	May	0.44	August	0.73	November	0.18
March	0.15	June	0.75	September	0.45	December	0.17

The net long-wave-length radiation absorbed by the ice surface is given by the formula:

$$IR_{ice} = IR_{water}(\text{Ratio}) \ . \tag{5}$$

Vowinkel and Orvig (1973) show that in all seasons the latent and sensible heat fluxes over ice are negative; i.e., directed into the ice surface. Further, there is surprisingly little difference in magnitude between the months and ice thickness. Consequently, single values for the latent and sensible heat fluxes have been used in the present work for all months and all thicknesses of ice, as follows:

$$LE_{ice} = -2 \text{ W m}^{-2}, \tag{6}$$

$$SE_{ice} = -9 \text{ W m}^{-2} \ . \tag{7}$$

The various fluxes corrected for the presence of ice and recorded on the magnetic tapes were computed using SIRAT in the same manner as in (4).

c) Recalculation of net infrared radiational exchange

During the course of the long-term flux computations it became apparent that computed flux gains by the ocean were not as accurate as anticipated. Computed fluxes over the Mediterranean Sea indicated that the water gained heat. However it is known from oceanographic observations that warm Atlantic surface water enters the sea via the Strait of Gibraltar, is cooled within the basin and returns to the Atlantic beneath the incoming surface water. All flux components contributing to net heat gain by the ocean were checked against energy budget determinations. It was concluded that solar and infrard radiation values were most questionable. Solar radiation estimates are questionable because they were calculated from tables based on measurements now known to have significant calibration errors. Also non-uniformities exist between the standards used by different nations. No changes to calculated solar radiation fluxes have been made because of these uncertainties.

A study of infrared heat exchange (to be published soon) was made by comparing net surface infrared radiational exchanges. Values derived following the Elsasser (1942) method using upper air observations, were compared with values derived using the Budyko (1963) empirical formula, which uses only surface observations. It was found that the formula was inadequate to calculate infrared exchanges whenever the upper air was more moist or less moist than an average value assumed by the formula. In regions of sub-tropical high pressure cells it was found that the net heat lost was about 10 W m^{-2} greater than the value calculated from the surface empirical formula. In the middle latitudes of the sub-tropical high the error was about zero. Long-term averages have been corrected by applying corrections directly to the averages. The present climate data set has been corrected by recalculating infrared fluxes from seasonal values of surface fluxes for each Marsden square under conditions of a) 8 oktas of low cloud, b) of 8 oktas of combined middle and high cloud, and of c) clear sky. Figures 2, 3, and 4 show the surface net infrared radiational exchange using the Ekman method during the northern winter for the 3 sky conditions. It is seen that the radiational fields show surprisingly little variation from arctic to antarctic regions. Hence average values for each Marsden square can be determined from the charts with confidence. Net fluxes were found by multiplying and summing the indicated fluxes for overcast conditions by the fraction of sky coverage by clouds of each type and the fraction of clear sky. An empirical formula to account for the air-sea temperature differences was determined using the Elsasser method. The flux equations used are as follows:

If $T_{air} - T_{sea} < 0.0$,

$$\text{IR Flux} = -4(T_{air}-T_{sea})(1+0.008(T_{air}-15)) + (N_L/8)(IR_{NL8}) + (N_{MH}/8)(IR_{MN8}) + (1-N_T/8)(IR_{CLR}) \quad (10)$$

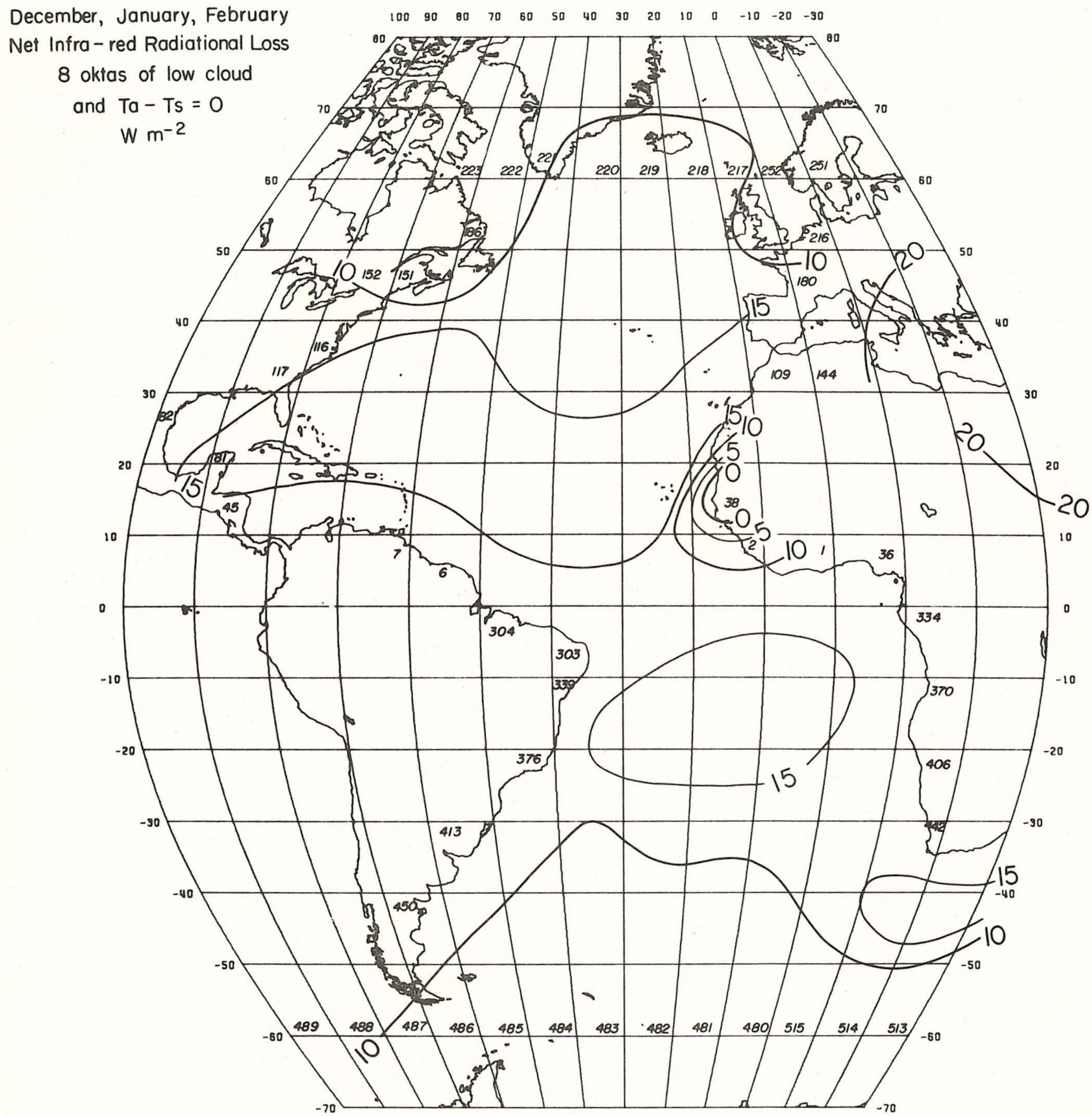

Figure 2. Chart of winter-time (N.H.) net infra-red radiational heat loss with 8 oktas of low cloud and no air-sea temperature difference. W m^{-2}.

December, January, February
Net Infra-red Radiational Loss
8 oktas of middle and high cloud
at 500 mb
Ta - Ts = 0
W m^{-2}

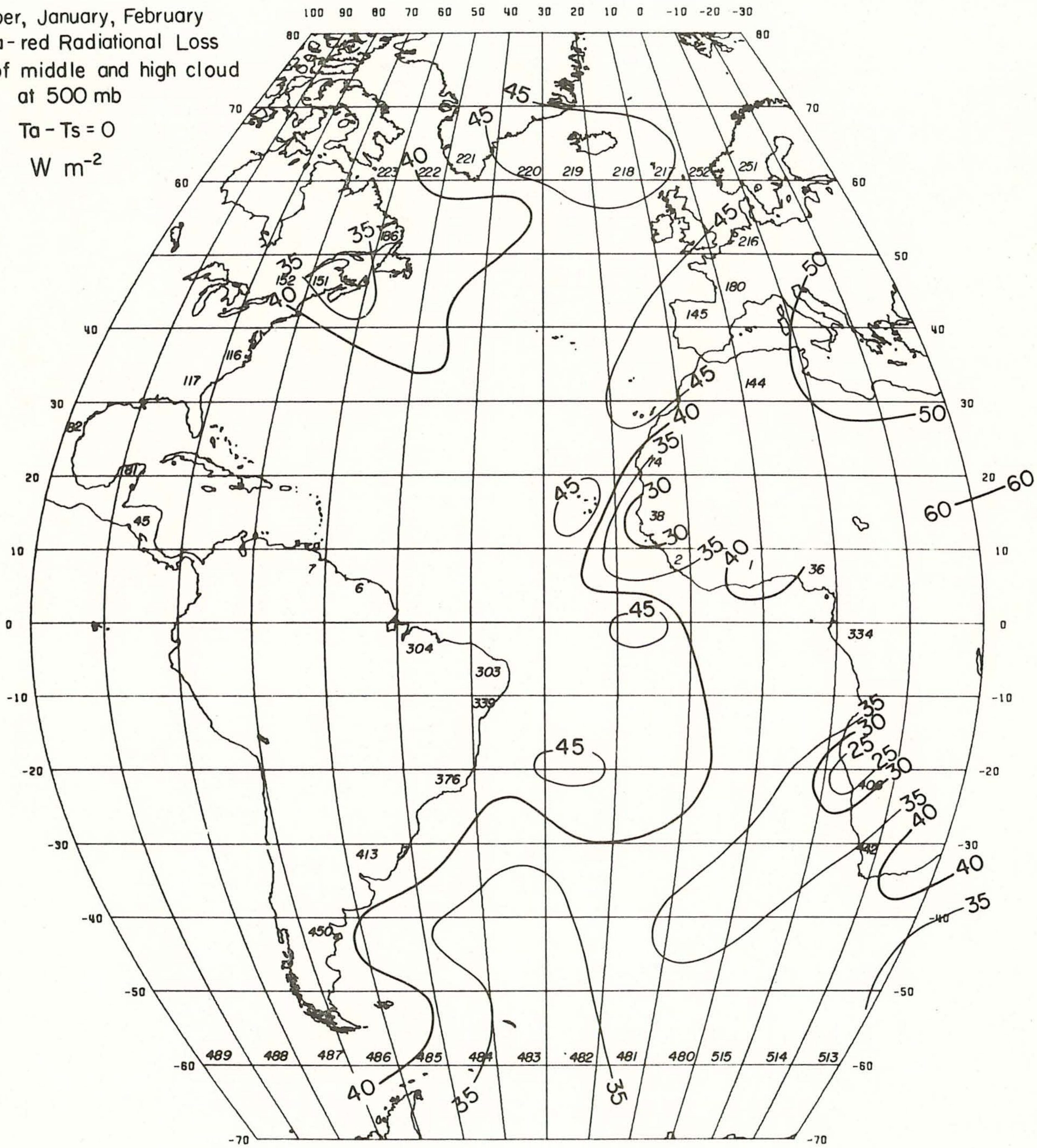

Figure 3. Chart of winter-time (N.H.) net infra-red radiational heat loss with 8 oktas of combined middle and high cloud at 500 mb and no air-sea temperature difference W m^{-2}.

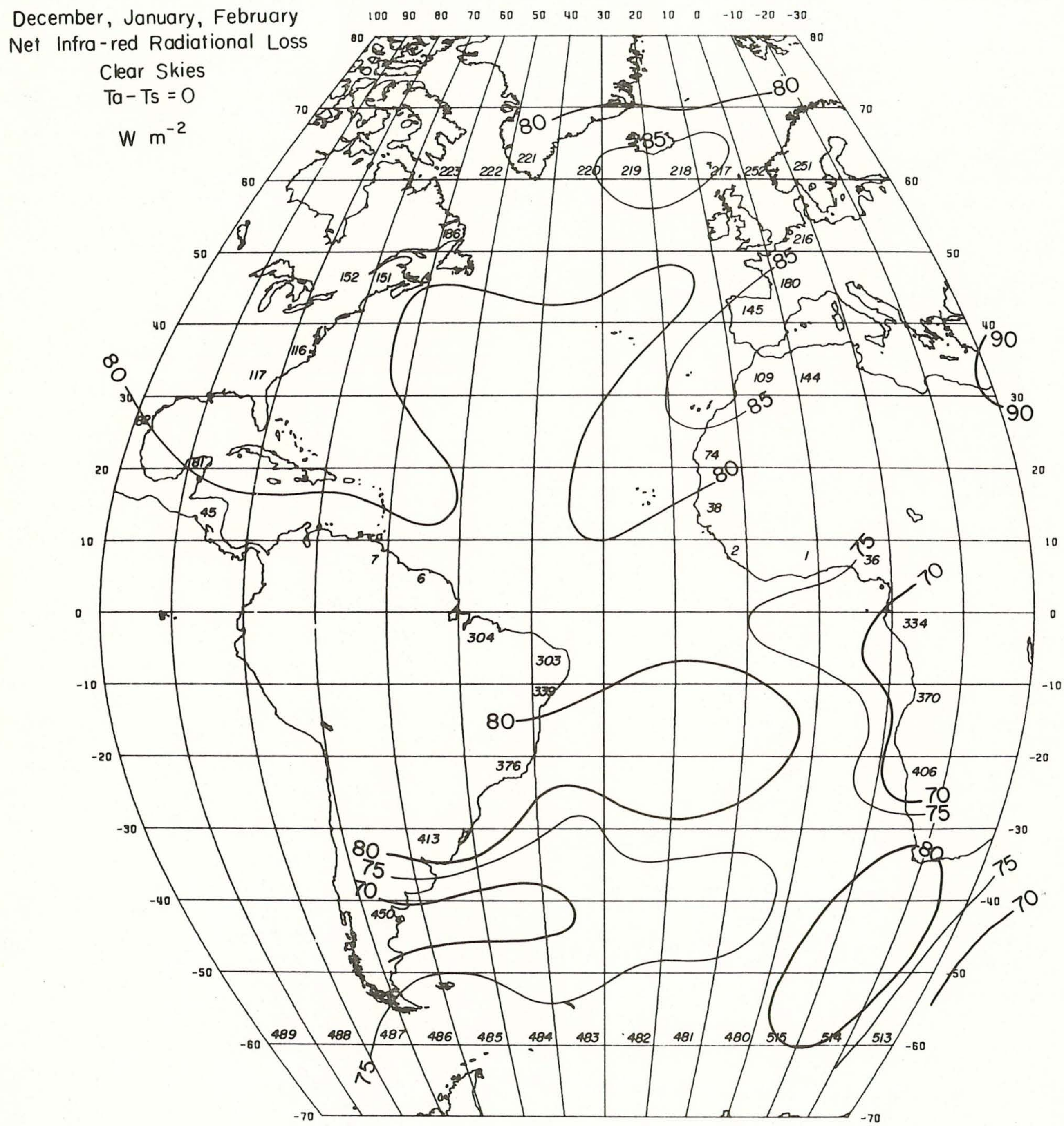

Figure 4. Chart of winter-time (N.H.) net infra-red radiational heat loss with clear skies and no air-sea temperature difference. W m^{-2}.

If $T_{air} - T_{sea} > 0.0$,

$$\text{IR Flux} = -0.96\ (T_{air}-T_{sea})(1+0.03(T_{air}-15)) + (N_L/8)(IR_{NL8})$$

$$+ (N_{MH}/8)(IR_{MN8}) + (1-N_T/8)(IR_{CLR})\ . \qquad (11)$$

Here IR_{NL8}, IR_{MN8}, and IR_{CLR} are the seasonal fluxes of infrared at the surface with 8 oktas of low cloud, 8 oktas of combined middle and high cloud assumed to be at 500 mb, and clear sky respectively. Since the amounts of low, middle and high cloud are not recorded on the magnetic tape, seasonal charts of ratios of low cloud amount(ing) to total amount were constructed from long-term averages and ratios for each square determined. The necessary values were entered into computer memory and the recomputations were carried out. Averages of the new fluxes were formed and compared to the old values. It was found that the corrections matched the long-term seasonal errors.

d. General corrections

A few erroneous values have been noted that passed the quality control limits set up for ship observations. For example, in one case a ship with a faulty barometer made several trips in the Gulf of Guinea in 1955 and reported several pressures around 920 mb. Latitude errors can cause unreasonable temperatures to appear in the listings of maximum and minimum temperatures in arctic and tropical regions. In squares with large numbers of observations such errors do not influence greatly the average and are ignored. In squares with only a few observations they can be eliminated and a new average formed.

4. Listing and format of data set

a) Organization of monthly averages

The average monthly values for the variables and fluxes have been archived in several formats for use at WHOI. The information contained is the same, however, and is described below.

The data is ordered into files by 10 degree Marsden square identifier. Within each data file there is a record for each month from January, 1948, through December, 1972. Each record contains the place and time identifiers, and the corresponding averages for the parameters and fluxes described in Table 3.

The first record of each file is a header record containing information which describes the format and content of the data records which follow. This header record is always in card image format; the contents of its various fields are given in Table 4. Mention should be made of the parameters CLAT and CLON, beginning with characters 38 and 43 respectively. These coordinates give the latitude and longitude of the center of the square weighted by the distribution of ship observations within the square. These distributions are based on the division of each 10 degree square into as many as ten subregions, as carried out in a previous project.[1]

The data records follow the header record. The number of data records can be determined from the start and end dates contained in the header record. The storage mode and record length are also contained in the header record. The data record always contains the Marsden identifier, year, and month codes. If there were no valid observations for the month, the remaining parameters will have a value of -99 inserted in the fields which follow.

---

[1] See footnote 1, page 2.

b) Listing of data

Each data file, including both header and data records, have been printed by computer line printer and is archived at Woods Hole. A partial list is shown in Table 5a. The format is as described in Table 3. Printed lists can also be obtained for selected parameters and 10 degree Marsden squares.

c) Magnetic tape archive of data

The data set is available on 2400-foot, 800 bpi, 9-track magnetic tape. These tapes contain the data in an internal WHOI-labeled tape format (LT), as well as in a more general unblocked EBCDIC file tape format (FT). The first file of an 'FT' tape contains an index of the files on the tape. Table 5b gives the first 10 entries in File 1 of tape FT #CL2A. Labeled tapes do not contain an index. A complete list of the climatological data tapes archived at WHOI is contained in Table 6 .

5. Statistics of fluxes and variables

a) Statistical methods

To facilitate the climatological analysis of the data set, a few fundamental statistical properties were computed and archived. A list of the terms found, for each of the 24 parameters in Table 1, is given in Table 7. Orthogonal polynomial regression was chosen as the coefficients are independent in their contribution to the sum of squares. Once the coefficients are obtained it is possible to compute the more familiar polynomial regression coefficients, standard deviations, etc.

TABLE 3

Data records 2 - 301:

parameter identifier	data element	columns	format
MSQR	1	1-4	I4
YEAR	2	5-9	I5
MON	3	10-13	I4
NOBS	4	14-19	I6
TAIR	5	20-24	F5.1
MIXR	6	25-27	I3
TSEA	7	28-32	F5.1
TASD	8	33-37	F5.1
CLOU	9	38-41	F4.1
WIND	10	42-44	I3
EAST	11	45-47	I3
NORT	12	48-50	I3
WDIR	13	51-54	I4
RAIN	14	55-58	F4.2
PRES	15	59-63	I5
ICER	16	64-67	F4.2
QSUR	17	68-73	F6.1
IRED	18	74-79	F6.1
REXB	19	80-85	F6.1
LATB	20	86-91	F6.1
SENB	21	92-97	F6.1
OHGB	22	98-103	F6.1
LATI	23	104-109	F6.1
SENI	24	110-115	F6.1
HGBI	25	116-121	F6.1
TAUX	26	122-126	F5.1
TAUY	27	127-131	F5.1

TABLE 4

ACS Data File Structure

EBCDIC

Header Record 1 - 80 bytes, EBCDIC

MRSQ	cols	1-4	right justified integer, 10 degree Marsden square identifier.
ISTYR		5-9	right justified integer, year of first data record, e.g., 1948.
ISTMN		10-13	right justified integer, month of first data record, e.g., 1.
ILYR		14-18	right justified integer, year of last data record in file, e.g., 1972.
ILMN		19-20	right justified integer, month of last data record in file, e.g., 12.
MODE		21-22	right justified integer, mode of data record storage: 0 = EBCDIC 1 = binary
IRECLEN		23-25	right justified integer, length of data records, in bytes.
MLAT		26-31	right justified integer, middle latitude of Marsden square, in degrees and hundredths.
MLON		32-37	right justified integer, middle longitude of Marsden square, in degrees and hundredths.
CLAT		38-42	right justified integer, weighted latitude center of observations, in degrees and hundredths.
CLON		43-48	right justified integer, weighted longitude center of observations, in degrees and hundredths.
NOBS		49-55	number of observations in Marsden square.

TABLE 5

a) Partial list of monthly averages in File #2 of FT #CL2A

```
DATA                                                                                                                                     3
  1 1948   1 197212 0132   500    500  321   592
  1 1948   1     31 27.0 19 27.4   -.4 3.6  3  1  1 219 .06 1011 .00 212.6  52.6 159.9  68.5   2.5  88.9  49.4   2.8 107.8  .00  .01
  1 1948   2     28 27.1 19 27.1    .0 3.8  3  0  1 193 .11 1010 .00 222.3  49.4 172.9  50.0   -.2 123.1  40.0   3.8 129.1  .00  .01
  1 1948   3     17 27.9 19 27.6    .3 5.1  4  0  2 186 .06 1010 .00 187.8  39.3 148.5  85.4  -2.5  65.6  56.0   4.5  88.1 -.01  .03
  1 1948   4     28 27.6 20 28.4   -.8 4.5  4  2  1 233 .11 1011 .00 205.2  47.4 157.8  98.1   7.4  52.2  70.9   7.2  79.7  .02  .02
  1 1948   5     39 26.8 18 27.8 -1.0  4.1  5 -1  4 160 .10 1012 .00 210.8  51.0 159.9 154.1  12.4  -6.7 115.5  10.4  34.0 -.02  .05
  1 1948   6     54 25.3 17 26.0   -.8 4.1  4  1  3 190 .04 1015 .00 208.0  48.8 159.3 108.1   7.9  43.2  84.8   9.2  65.3  .01  .03
  1 1948   7     24 24.1 15 25.3 -1.1  5.1  5  1  4 187 .04 1015 .00 178.4  42.8 135.6 153.9  15.3 -33.5 116.4  11.8   7.5  .01  .05
  1 1948   8     63 23.7 16 24.3   -.6 5.2  4  1  3 195 .06 1015 .00 174.6  39.9 134.7  78.5   6.6  49.7  64.7   8.5  61.6  .01  .04
  1 1948   9     28 24.1 16 24.8   -.6 4.8  5  0  4 176 .00 1014 .00 197.2  41.1 156.1  99.6   7.2  49.4  75.9   7.4  72.9  .00  .05
```

b) Partial list of indices in File #1 of Tape FT #CL2A

```
DATA
  1 1948   1 197212 0132   500   500  321   592  35201  0S001    909 CL01
  2 1948   1 197212 0132   500  1500  594  1434 105207  0S002    909 CL01
  3 1948   1 197212 0132   500  2500  546  2639  40619  0S003    909 CL01
  4 1948   1 197212 0132   500  3500  356  3430  24680  0S004    909 CL01
  5 1948   1 197212 0132   500  4500  452  4507  47086  0S005    909 CL01
  6 1948   1 197212 0132   500  5500  761  5403  36066  0S006    909 CL01
  8 1948   1 197212 0132   500  7500  797  7827  14764  1S008    909 CL01
 36 1948   1 197212 0132   500  -500  350  -489   8990 38S036    909 CL01
 38 1948   1 197212 0132  1500  1500 1497  1717 108597  0S038    909 CL01
 39 1948   1 197212 0132  1500  2500 1490  2472  50010  0S039    909 CL01
```

TABLE 6

A Complete List of the Climatological Data Tapes Archived at WHOI

INDEX ØF TAPES CURRENTLY IN USE FØR THE ATLANTIC CLIMATØLØGICAL STUDY

TAPE		CØNTENTS
LT#CL01	-	DATA FILES, EBCDIC, 1948-1972
LT#CL02	-	WEATHER SHIP DATA FILES, EBCDIC, 1948-1972
LT#CL03	-	STATISTICS FILES, EBCDIC, 1948-1972
LT#CL04	-	WEATHER SHIP STATISTICS FILES, EBCDIC, 1948-1972
LT#CL11	-	DATA FILES, BINARY, 1948-1972
LT#CL12	-	WEATHER SHIP DATA FILES, BINARY, 1948-1972
LT#CL13	-	STATISTICS FILES, BINARY, 1948-1972
LT#CL14	-	WEATHER SHIP STATISTICS FILES, BINARY, 1948-1972
FT#CL2A	-	N. ATL. DATA FILES, EBCDIC, 1948-1972, FIRST FILE INDEX
FT#CL2B	-	S. ATL. DATA FILES, EBCDIC, 1948-1972, FIRST FILE INDEX
FT#CL23	-	N. ATL. STATISTICS FILES, EBCDIC, 1948-1972, FIRST FILE INDEX
FT#CL24	-	S. ATL. STATISTICS FILES, EBCDIC, 1948-1972, FIRST FILE INDEX
LT#CL31	-	BACKUP FØR CL11
FT#CL3A	-	N. ATL. DATA FILES, BINARY, 1948-1972, FIRST FILE INDEX
FT#CL3B	-	S. ATL. DATA FILES, BINARY, 1948-1972, FIRST FILE INDEX
FT#CL33	-	STATISTICS FILES, BINARY, 1948-1972, FIRST FILE INDEX

Program RLFOTH and other subroutines from the International Mathematical and Statistical Library (1975) were used to compute the orthogonal polynomial regression coefficients. RLFOTH was written from a formulation of the problem by Forsythe (1957).

As with the monthly averages data, the statistical data is ordered into files by 10 degree Marsden square identifier. The first record of each file is again a header record, as described in Table 4. The information for a given Marsden square will be the same as for the data file, with the exception of the fields for the identifiers MODE and IRECLEN. These will, of course, be different reflecting the storage format used.

Within the file the statistical quantities have been computed for 18 different time periods, or seasons. The seasons chosen are given in Table 8. In general, there is a record in the file for each parameter, over all seasons.

Because a third order polynomial was used for the computation of coefficients, at least three seasonal components were required from the monthly average data for the 10 degree square. If this criteria was not met, the statistical quantities for all parameters (5-27 in Table 1) were set equal to zero. The number of seasonal components, parameter 4, will be left unchanged however, in the range 0 through 3.

The above statistical procedures were used on all parameters. Statistics computed for the wind direction in this manner frequently are meaningless. This is because of the discontinuous nature of coding (360° = 0°) the direction. The vector components of the wind (east and north) are available and the direction may be determined from them.

b) List of statistical parameters

Each 10 degree square statistics file has been summarized on the line printer and archived at WHOI. The format has been slightly altered to present the researcher with more usable information. Those quantities included on the output are listed below. An example for one season is given in Table 9.

- orthogonal polynomial regression coefficients C0, Cl, C2, C3 for orders 0 through 3. This includes the mean as the zeroeth order coefficient C0;
- number of months used in computing the coefficients;
- residual sum of squares;
- standard deviation, σ;
- standardized orthogonal polynomial regression coefficients Cl', C2' C3', where Cl' = Cl/σ.
- sum of the squares contribution F-ratios;
- linear polynomial regression coefficient in units per year.

c) Magnetic tape archive of statistics

The basic statistical parameters referred to in 5a, above, have been stored on 2400 foot, 800 bpi, 9-track magnetic tape at WHOI. Each file contains the computed coefficients, transformation constants used, etc. as given in Table 7 for all 18 seasons for parameters 4 through 27 of the 10 degree square. These tapes have been archived in an internal WHOI

TABLE 7.

Archived Statistics for Climatological Data

N	Number of monthly average values comprising the seasonal quantity.
C0	Average, or zeroeth, degree regression coefficient for the fitted orthogonal polynomial.
C1	First order regression coefficient for the fitted orthogonal polynomial.
C2	Second order regression coefficient for the fitted orthogonal polynomial.
C3	Third order regression coefficient for the fitted orthogonal polynomial.
A	An internal transformation constant used to normalize the distribution of observation times.
B	An internal transformation constant used to normalize the distribution of observation times.
ST	Uncorrected total sum of square.
S0	Sum of squares attributable to the mean.
S1	Sum of squares attributable to the first order component of the orthogonal polynomial.
S2	Sum of squares attributable to the second order component of the orthogonal polynomial.
S3	Sum of squares attributable to the third order component of the orthogonal polynomial.
SE	Sum of squares attributable to the error, i.e., residual.

TABLE 8.

Numeric codes for climatological time periods

1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
10	October
11	November
12	December
13	Spring (consecutive March, April, May)
14	Summer (consecutive June, July, August)
15	Fall (consecutive September, October, November)
16	Winter (consecutive December, January, February)
17	Annual (all months in the year must have been present)
18	Total - all months for which there were observations.

format as well as in a more general unblocked, EBCDIC format. A complete list of the climatological tapes archived at WHOI is contained in Table 6.

6. Processing software

During the course of this project, several computer programs have been developed. While the file accessing techniques are restricted in their use to the WHOI facility, the programs themselves are written in FORTRAN IV Extended as implemented on the Xerox Sigma 7.

Utility program allow the retrieval of selected data or statistical elements for a specified parameter and time period. Processing programs are also available which perform the following types of operations:

- list monthly averages for selected parameters by 10 degree square;
- order and list 10 degree squares by magnitude of anomaly;
- order and list 10 degree square by standard deviation;
- return to an on-line user the mean, standard deviation, and polynomial regression coefficients for a selected 10 degree square, parameter, and seasonal time reference;
- plot time series of monthly average values for selected parameters;
- plot spatial map of the Atlantic Ocean with annotation by specified data or statistical elements.

TABLE 9

Sample of Statistics Printed Output

SUMMARY FOR ALL APRIL 1/1948 TO 12/1972
MARSDEN SQUARE 1 LAT = 5. LON = 5.

NUMBER OF PERIODS: 25
MONTHS (FROM 1/1948 = 0) 3.0 15.0 27.0 39.0 51.0 63.0 75.0 87.0 99.0 111.0 123.0 135.0 147.0 159.0 171.0 183.0 195.0 207.0 219.0 231.0 243.0 255.0 267.0 279.0 291.0

ORTHOGONAL POLYNOMIAL REGRESSION

		Coefficients: Average C0	C1	C2	C3	Standardized by S.D.: C1'	C2'	C3'	Sum of Squares: Residual	F-Ratios: 1st Deg	2nd Deg	3rd Deg	Standard Dev.	Poly Regress 1st Deg Unit/Yr	ID
4	NOBS	129.36	77.19	-.91	-65.05	.39274	-.00462	-.33098	5.186E 05	8.7126	.0014	7.8280	196.5383	12.865	4
5	TAIR (CENT)	28.04	-.01	.14	.11	-.01476	.26463	.21504	5.361E 00	.0087	3.2188	2.3380	.5316	-.001	5
6	MIXR (G/KG)	19.76	-.12	.22	.17	-.17396	.33784	.25395	6.697E 00	1.5077	6.5390	4.0643	.6633	-.019	6
7	TSEA (CENT)	28.89	.01	-.20	.08	.02375	-.34972	.13662	5.735E 00	.0237	5.9091	.9920	.5637	.002	7
8	TASD (CENT)	-.85	-.01	.33	.03	-.01738	.45546	.04764	7.853E 00	.0150	11.8468	.1426	.7171	-.002	8
9	CLOU (OKTAS)	4.86	.23	-.16	.01	.28052	-.19529	.01684	1.319E 01	3.0505	1.7002	.0139	.8210	.038	9
10	WIND (M/SEC)	3.68	.10	.26	.03	.13569	.35397	.04079	1.011E 01	.7732	6.0514	.0884	.7483	.017	10
11	EAST (M/SEC)	.68	.00	.14	-.04	.00669	.20249	-.05936	1.055E 01	.0015	1.6154	.1527	.6904	.001	11
12	NORT (M/SEC)	1.96	.18	.17	.18	.23383	.21520	.22259	1.112E 01	2.3244	2.2639	2.6643	.7895	.031	12
13	WDIR (FROM N)	202.24	-1.83	2.26	-1.75	-.09452	.11671	-.09036	8.503E 03	.2979	.5224	.3445	19.3375	-.305	13
14	RAIN (RATIO)	.17	.01	-.04	-.00	.10429	-.38006	-.04241	2.128E-01	.4706	7.1873	.0985	.1102	.002	14
15	PRES (PASC/100)	1010.16	-.14	.09	-.02	-.10117	.06101	-.01359	4.293E 01	.3616	.1512	.0082	1.4142	-.024	15
16	ICER (RATIO)	.00	.00	.00	.00	.00000	.00000	.00000	.000E 00	.0000	.0000	.0000	.0000	.000	16
17	QSUR (W/M**2)	191.16	-7.12	5.55	-.83	-.26752	.20846	-.03131	1.387E 04	2.7737	1.9369	.0481	26.6208	-1.187	17
18	IRED (W/M**2)	45.25	-1.45	-.17	-.12	-.29599	-.03443	-.02553	4.951E 02	3.2006	.0498	.0301	4.8838	-.241	18
19	REXB (W/M**2)	145.91	-5.67	5.72	-.72	-.24989	.25219	-.03194	9.795E 03	2.4849	2.9104	.0513	22.6713	-.944	19
20	LATB (W/M**2)	110.60	1.76	-4.52	1.03	.06441	-.16542	.03773	1.690E 04	.1389	1.0536	.0603	27.3168	.293	20
21	SENB (W/M**2)	7.41	-.04	-2.95	-.35	-.00537	-.41369	-.04885	8.537E 02	.0013	8.8930	.1364	7.1320	-.006	21
22	OHGB (W/M**2)	27.87	-7.39	13.20	-1.41	-.14326	.25591	-.02726	5.452E 04	.7590	2.7853	.0348	51.5626	-1.231	22
23	LATI (W/M**2)	83.50	2.36	-6.60	1.68	.09204	-.25726	.06556	1.367E 04	.3096	2.7816	.1987	25.6640	.394	23
24	SENI (W/M**2)	8.12	-.07	-2.27	.34	-.01153	-.39914	.05964	5.567E 02	.0059	8.0699	.1982	5.6864	-.011	24
25	HGBI (W/M**2)	54.29	-7.96	14.59	-2.75	-.15752	.28861	-.05433	4.985E 04	.9644	3.7233	.1451	50.5458	-1.327	25
26	TAUX (PASCAL)	.01	.00	.00	.00	.13077	.25043	.06941	2.008E-03	.6308	2.6604	.2248	.0099	.000	26
27	TAUY (PASCAL)	.02	.00	.00	.00	.20491	.27444	.15863	3.107E-03	1.7489	3.6077	1.3259	.0131	.000	27

References

Budyko, M. I., 1963: Atlas of heat balance of the world. Glabnaia Geofiz. Observ. Also, GUide to the Atlas of the heat balance of the Earth, Transl. I. A. Donehoo, U. S. Wea. Bur. WB/T-106, Washington, D.C.

Bunker, A. F., 1976: Computations of surface flux and annual air-sea interaction cycles of the North Atlantic Ocean. Mon. Wea. Rev. 104, 1122-1140.

-------------, and L. V. Worthington, 1976: Energy exchange charts of the North Atlantic Ocean. Bull. Am. Meteor. Soc. 57, 670-678.

Elsasser, W. M., 1942: Heat transfer by infrared in the atmosphere. Harvard Meteor. Studies, No. 6, Harvard Univ. Blue Hill Meteor. Observ., 197 pp.

Forsythe, G. E., 1957: Generation and use of orthogonal polynomials for fitting data with a digital computer. J. Soc. Indust. Appl. Math. 5, 74-88.

International Math. and Stat. Libr. Inc., 1975: International mathematical and statistical library. Vols. 1 and 2, Houston, Texas.

Larsson, P. and S. Orvig, 1961: Atlas of mean monthly albedo of Arctic Surfaces. Publ. in Meteor. No. 45. McGill Univ. 41 pp.

-----------------------, 1962: Albedo of Arctic surfaces. Publ. in Meteor. No. 54. McGill Univ. 41 pp.

Vowinckel, E., and S. Orvig, 1973: Synoptic energy budgets from the Beaufort Sea. Proc. SYmp. ENergy fluxes over polar surfaces, Moscow, 3-5 August 1971. WMO No. 361. 143-166.

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Time-series of monthly averages of latent, sensible and radiational heat fluxes and momentum fluxes at the surfaces of the North and South Atlantic Oceans were calculated from ship weather observations. These fluxes, together with values of meteorological variables have been averaged over entire Marsden squares ($10x10^{o}$ squares) for all months from January 1948 through December 1972. The method of computing fluxes from ship weather observations, listing of variables averaged, addition of sea-ice coverage of sub-polar regions, correction of albedos for the presence of sea ice, correction of infrared radiational exchange for humidity conditions of the upper atmosphere, and format of the data on magnetic tapes are described. Statistics of the fluxes and variables have been computed. Standard data tapes containing these time series and statistics are available.

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